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Geophysical Study of Aquifer Properties at Isihor Village of Edo State, Nigeria

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Abstract

The primary objective of this research work, is to reduce youth restiveness in the area to its lowest ebb by setting up additional pure water industry or factory where these youths will be gainfully employed and hence the need to prospect or search for additional aquifer or water bearing formations became inevitable.

Ten (10) vertical electrical sounding (VES) (uniformly distributed) based on electrical resistivity method was carried out in a geophysical survey in order to study aquifer properties. These properties include depth, thickness and nature of soil above the aquifer. Schlumberger array of VES was conducted in Isihor Village and its environs area of Edo state, Nigeria. The resistivity soundings were carried out with semi current electrode spacing in the range 1-632m using six (06) points per decade to determine the depth, thickness of the recommended aquifer. The geophysical results were used to determine the depth, thickness of the recommended aquifer or water bearing formation and the thickness of the sandy soil above it. The resistivities of the detected aquifer varied from 800 ohm-m to 9000 ohm-m while its depths varied from 15m to 120.0m. The thickness of the detected aquifer which varied from 10m to 60m enable us to known the probable area for future drilling operation.

1.0 Introduction:

Electrical resistivity method has gradually and continually made its way to the top in the successful search and exploitation of aquifer properties. [1]. This method has been recognized to be more suitable and reliable for hydrogeological or groundwater survey of sedimentary basin [2]. The necessity of obtaining portable water within an environment is pertinent. It is a major determinant of population growth. The advent of technological advancement has made the quest for water for domestic, industrial and agricultural consumption to drift from mere search for surface water (flowing or stagnant pools) to prospecting for steady reliable subsurface or ground water from boreholes [3]. In many parts of the country today, groundwater is being sought for by many companies to meet the demand of water by individual parastatal local, state and federal Government. Records show that the depths of aquifers or water bearing formations differ from place to place because of variational geothermal and geostructural occurrence. Although, Nigeria is said to have abundance of underground water, borehole studies even in parts of Isihor village of Edo State show evidence of dry wells [5].

The research work reported here was carried out primarily using geophysical prospecting to determine the aquifer attributes or properties such as depths, thicknesses and the nature of soil materials above the recommended aquifer for the purpose of portable water production which could serve the community by way of irrigation, navigation, industrialization, e.t.c

The study area was Isihor village of Edo state in Nigeria which lies on latitude and longitude of about $6^0$25’ N and 5^0 24E respectively [6].

EXPERIMENTAL WORK

Schlumberger array of vertical electrical sounding (VES) was employed for this research work, details explanation of the principle using the equipment ABEM AC 300 terrameter and its SAS 2000 Booster have been documented [7].

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The operational principle of the method is based on the computation of apparent resistivity ℓ_a formula which have been documented [8], [9] [10] [11] [12].

The apparent resistivity values were plotted against semi-current electrode spacing (AB/2) using 1P12/WINREST software. The resulting set of layer parameters were interpreted in terms of their lithologies driller's log to obtain aquifer layer depths and thicknesses [3].

BRIEF LOCAL GEOLOGY OF THE STUDY AREA

The study area which is Isihor village in Edo State, Nigeria is underlained by Benin formation [14]. The topography of the area is a plane surface area which has the rock types (lithologies): topsoil, laterite, clay, sandy clay and clean sand in agreement with the Benin formation which ranges from Miocene to recent [15].

Isihor village which is located at about 4.03km away from the university of Benin in Ovia North-East Local Government Area of Edo State, Nigeria has latitude and longitude of about 6^0 25^1N and 5^0 24^1E respectively [6]

THEORETICAL ANALYSIS

The basic theory behind electrical resistivity method have been demonstrated in previous research work [8] [9] [10] [11] [12]

In a homogeneous Isotropic medium, the potential due to a single point current source such as the current electrode, satisfy laplace's aquation arising from the equipotential surface that is clearly hemispherical so that

$$E = -\nabla V \text{ and } J = \sigma E \quad (4.1)$$

$$\therefore J = -\sigma\nabla V \quad (4.2)$$

Where ∇ = del operator = $\hat{\imath}\frac{d}{dx} + \hat{\jmath}\frac{d}{dy} + \hat{k}\frac{d}{dz}$ (4.3)

V = Electric potential, E = electric field intensity

σ = conductivity, J. = Current density

The mathematical analysis of (4.1), (4.2) and (4.3) which yielded

$$\nabla^2 V = 0 \quad (4.4)$$

have been documented [7] where ∇^2 (del squared is the usual laplacian operator such that $\nabla^2 = \frac{d^2}{dx^2} + \frac{d^2}{dy^2} + \frac{d^2}{dz^2}$

The solution to equation (4.4) may be developed from first principle for a particular earth's model by selecting a co-ordinate system to match the earth's model geometry and imposing appropriate boundary or initial condition. This solution usually yield apparent resistivity ℓ_a as a function of the electrodes array namely AB/2, MN/2, electric current I and potential difference ΔV [10]

The calculated apparent resistivity ℓ_a according to schlumberger array condition of AB$\geq$ 5MN is

$$\ell_a = \pi\left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN}\right]\frac{\Delta V}{I} \quad (4.5)$$

AB = Current Electrodes spacing in meter

MN = potential electrodes spacing in meter

ΔV = potential difference in volt, I =- electric current in Amperes, $\pi = \frac{22}{7}$ [11]

RESULTS AND DISCUSSION

The results of the vertical electrical sounding (VES) obtained from geophysical survey is a function of apparent resistivity (ℓ_a)and current electrode separation. This produced the computer iterated sounding (curves shown in figures 5.1-5.6.) and lithologies for the VES stations shown in tables 5.1-5.6 computer iteration techniques was employed by using software IP12WIN.

The lithologies or rock types of the different layers were then confirmed by using nearby borehole/driller's log of the area [16]

We usually harmonise borehole/driller's log of the area with standard table of electrical resistivities of some rocks and soil for Benin formation [17] for the purpose of interpretation because it is possible for different rock types to have the same range of resistivities [17] which usually make electrical resistivity data ambiguous to interprete.

By comparing the resistivity results with the borehole/driller log lithology, resistivity interpretation for the VES stations 1-6 was obtained.

VES stations 1,2 and 3 produced aquiferous zones because the last four layers of sandy clay, sandy soil, clean sand and clayey sand as shown in tables 5.1-5.3 are aquifers or water bearing formations.

In VES station 1, the fifth layer with a depth of about 38.83m to aquifer(s) is probably composed of sandy clay (first aquifer). The sixth aquiferous layer with a depth of 80.76m to second aquifer is probably composed of sandy soil. The seventh and eighth aquiferous layers with depth of 115.09m to third aquifer is probably composed of clean sand.

In VES station 2, the fourth aquiferous layer with a depth of 24.71m to first aquifer layer is probably composed of clayey sand. The fifth aquiferous layer with a depth of 51.92m to second aquifer is probably composed of clean sand. Also the sixth and seventh layers with depth of 109.83m to third aquifer layer is probably composed of clean sand.

In VES station 3, the last four layers represent aquiferous zone of clean sand with a total depth of 103.21m to aquifer.

Generally, as seen in tables 5.1 to 5.6 the resistivities of the detected aquifer varied from 800 ohm –m to 9000 ohm-m while its depth varied from 15m to 120m. The thickness of the detected aquifer varied from 10m to 60m. These results agreed very well with the driller's/borehole log of the area.

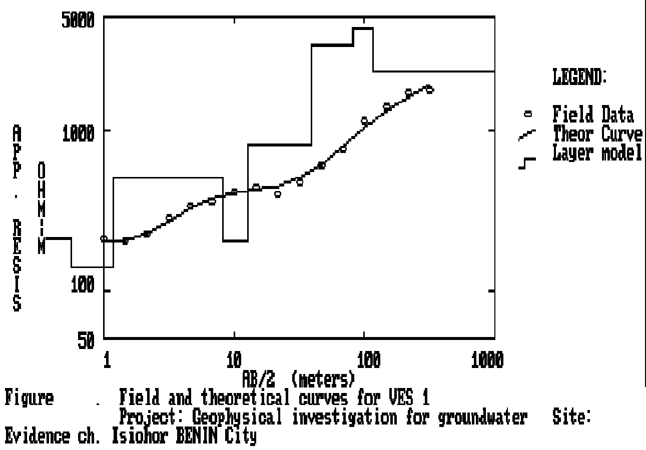

Fig 5.1 Iterated Sounding Curve For VES Station 1

Table 5.1: Lithology for VES station 1

Layer	**Resistivity (ohm-m)**	**Thickness (m)**	**Cum thickness (m)**	Inferred lithology
1	209.00	0.56	0.56	Top soil
2	138.99	0.64	1.20	Top soil
3	500.89	7.01	8.21	Laterite
4	198.55	4.61	12.82	Clay soil
5	813.00	26.01	38.83	Laterite
6	3361.00	41.93	80.76	Sandy soil
7	4303.00	34.33	115.09	Sandy soil
8	2336.00	Infinity	Infinity	Clean sand

Table 5.2: Lithology for VES station 2

Layer	**Resistivity (ohm-m)**	**Thickness (m)**	**Cum thickness (m)**	Inferred lithology
1	256.50	0.82	0.82	Top soil
2	181.00	1.62	2.51	Top soil
3	394.00	2.85	5.36	Laterite
4	1376.00	19.35	24.71	Sandy clay
5	5416.00	27.06	51.77	Sandy soil
6	8048.00	58.06	109.83	Clean sand
7	1990.00	Infinity	Infinity	Clean sand

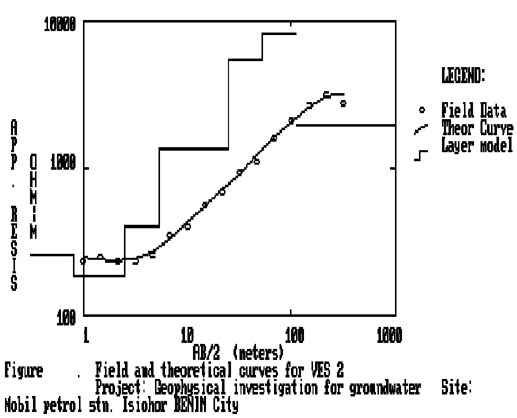

Fig 5.2 Iterated Sounding Curve For VES Station 2

Table 5.3: Lithology for VES station 3

Layer	Resistivity (ohm-m)	Thickness (m)	Cum thickness (m)	Inferred lithology
1	141.00	0.71	0.71	Top soil
2	324.00	1.21	1.92	Laterite
3	260.00	2.36	4.28	Clayey soil
4	1310.00	8.20	12.48	Sand clay
5	1455.00	13.24	25.72	Sandy soil
6	2907.00	27.06	52.78	Sandy soil
7	2664.00	16.10	68.88	Sandy soil
8	5250.00	34.33	103.21	Clean sand
9	1009.00	Infinity	Infinity	Clean sand

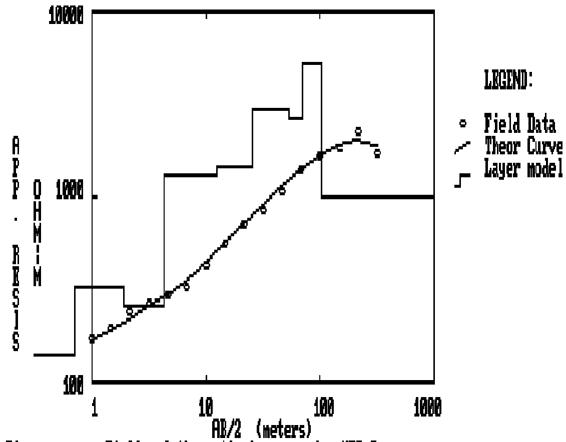

Figure . Field and theoretical curves for VES 3
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Fig 5.3: Iterated Sounding Curve for VES Station 3

Table 5.4: Lithology for VES station 4

Layer	Resistivity (ohm-m)	Thickness (m)	Cum thickness (m)	Inferred lithology
1	42.67	0.86	0.86	Top soil
2	186.12	1.59	2.45	Top soil
3	788.70	0.98	3.43	Laterite
4	621.11	3.99	7.42	Laterite
5	4994.23	6.22	13.64	Laterite
6	15,452.86	6.40	20.04	Loose sand
7	28014.02	8.87	28.91	Loose sand
8	14,199.97	14.49	43.40	Loose sand
9	7630.89	23.73	67.13	Clean sand
10	3512.61	30.90	98.03	Sandy soil
11	1202.12	Infinity	Infinity	Clean sand

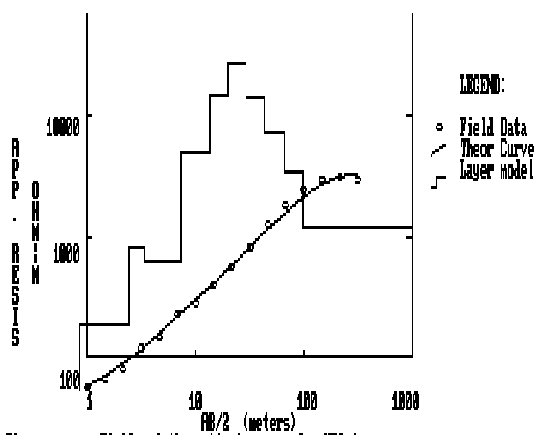

Figure . Field and theoretical curves for VES 4
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Fig 5.4 : Iterated Sounding Curve for VES Station 4

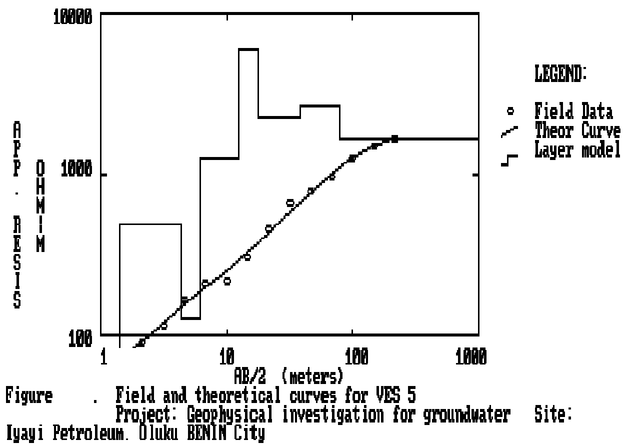

Fig 5.5 Iterated Sounding Curve for VES Station 5

Table 5.5: Lithology for VES station 5

Layer	**Resistivity (ohm-m)**	**Thickness (m)**	**Cum thickness (m)**	Inferred lithology
1	61.30	1.40	1.40	Top soil
2	496.00	2.98	4.38	Laterite
3	125.00	1.78	6.16	Clayey soil
4	1285.00	6.42	12.58	Laterite
5	60.00	5.10	17.68	Sandy soil
6	2259.00	20.37	38.05	Sandy soil
7	2635.74	39.83	77.88	Sandy soil
8	1662.12	Infinity	Infinity	Clean sand

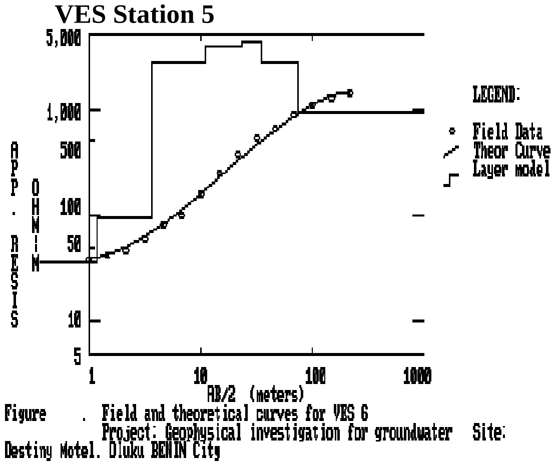

Fig 5.6 Iterated Sounding Curve for VES Station 5

Table 5.6: Lithology for VES station 6

Layer	**Resistivity (ohm-m)**	**Thickness (m)**	**Cum thickness (m)**	Inferred lithology
1	31.73	0.25	0.25	Top soil
2	37.00	0.92	1.17	Top soil
3	94.00	2.48	3.65	Top soil
4	27340.30	7.42	11.07	Laterite
5	3850.35	12.58	23.65	Laterite
6	4384.00	10.95	34.60	Laterite
7	2786.40	39.83	74.43	Laterite
8	933.16	Infinity	Infinity	Clean sand

CONCLUSION

Geophysical survey based on electrical resistivity method has proved useful and successful in the delineation of subsurface aquifer layers. The results of the interpreted electrical resistivity data revealed an unconfined aquifer of clean sand that recharges rapidly by precipitation with rising and falling water-table during wet and dry seasons and therefore recommended for water production. Hence the major unconfined aquifer intercepted in VES station 1 with a thickness of about 34.33m at a depth below sea level of about 115.09m and resistivity 4303 ohm-m may not dry up for a long time after the sinking of bore-hole if handled by a competent bore hole driller. This research work therefore serves as a working guide for a competent bore-hole driller in this Isihor village area where source of pure portable water is a major problem.

The thickness of the rock types or sandy soil above it was about 41.93m at a depth of about 80.76m below sea level.

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